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PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Kenneth James YOUNG et al.

Application No.: 10/734,129

Filed: December 15, 2003 Docket No.: 118114

For: COMBUSTION CHAMBER FOR GAS TURBINE

CLAIM FOR PRIORITY

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The benefit of the filing date of the following prior foreign application filed in the following foreign country is hereby requested for the above-identified patent application and the priority provided in 35 U.S.C. §119 is hereby claimed:

Great Britain Patent Application No. 0229755.4 filed on December 23, 2002

In support of this claim, a certified copy of said original foreign application:

☒ is filed herewith.

It is requested that the file of this application be marked to indicate that the requirements of 35 U.S.C. §119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of this document.

Respectfully submitted,

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JAO:JSA/amo

Date: June 15, 2004

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The Patent Office
Cardiff Road
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1. Your reference PAT/GPW/3061

2. Patent application number *(The Patent Office will fill in this part)* 0229755.4 23 DEC 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

ROLLS-ROYCE plc
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GREAT BRITAIN

Patents ADP number *(if you know it)* 3970002

If the applicant is a corporate body, give the country/state of its incorporation GREAT BRITAIN

4. Title of the invention COMBUSTION CHAMBER FOR GAS TURBINE ENGINE

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Patents ADP number *(if you know it)* 3970005

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

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Date 23-12-02

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DUPLICATE

COMBUSTION CHAMBER FOR GAS TURBINE ENGINE

This invention relates to combustion chambers for gas turbine engines, and in particular concerns lean burn, low emission combustion chambers having one or more resonator chamber for damping pressure fluctuations in the combustion chamber in use.

Lean burn, low emission gas turbine engine combustors of the type now being developed for future engine applications have a tendency, under certain operating conditions, to produce audible pressure fluctuations which can cause premature structural damage to the combustion chamber and other parts of the engine. These pressure fluctuations are audible as rumble which occurs as a result of the combustion process.

Pressure oscillations in gas turbine engine combustors can be damped by using damping devices such as Helmholtz resonators, preferably in flow communication with the interior of the combustion chamber or the gas flow region surrounding the combustion chamber.

The use of Helmholtz resonators has been proposed in a number of earlier published patents including for example US-A-5,644,918 where a plurality of resonators are connected to the head end, that is to say the upstream end, of the flame tubes of an industrial gas turbine engine combustor. This type of arrangement is particularly suitable for industrial gas turbine engines where there is sufficient space at the head of the combustor to install such damping devices. The combustor in a ground based engine application can be made sufficiently strong to support the resonators and the vibration loads generated by the resonators in use. This arrangement is not practicable for use in aero engine applications where space, particularly in the axial direction of the engine, is more limited and component weight is a significant design consideration.

A different approach to combustion chamber damping is therefore required for aero

engine applications where space is more limited and design constraints require that the resonators are supported with respect to the combustion chamber without adding appreciably to the weight of the combustion chamber itself.

According to an aspect of the present invention there is provided a combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a resonator cavity and a damping tube in flow communication with the interior of the combustion chamber, the tube having at least one cooling hole extending through the wall thereof.

The above arrangement provides for cooling of the damping tube of a Helmholtz resonator in flow communication with the interior of the combustion chamber. This can prevent overheating of the damping tube particularly in the region towards the end of the tube which opens into the interior of the combustion chamber. The present inventors have also found that the cooling hole or holes provides for improved damping performance of the Helmholtz resonator. It is to be understood that the term "cooling hole" used herein refers to any type of aperture through which cooling air or other fluid can pass.

In preferred embodiments, a plurality of cooling holes are provided in the wall of the tube. In this way it is possible to more uniformally cool the interior surface of the tube, particularly in embodiments where the holes are circumferentially spaced in one or more rows extending around the circumference of the tube. By spacing the cooling holes in this way it is possible to generate a film of cooling air on the interior surface of the tube wall in the region of the combustion chamber opening. This is particularly important since the film can protect the tube from the effects of the high temperature combustion gases entering and exiting the damping tube during unstable combustor operation.

Preferably, the combustion chamber comprises a plurality of axially spaced rows of cooling holes. By having two or more rows of cooling holes greater cooling efficiency can be achieved.

In preferred embodiments, the holes are angled with respect to the longitudinal axis of the tube. This can prevent separation of the cooling air passing through the holes from the interior surface of the tube in the region of the holes. This arrangement also promotes flow of cooling air in the longitudinal direction of the tube.

Preferably, the holes are angled in a direction towards the combustion chamber end of the tube such that the respective axis of the holes converge in the direction of the combustion chamber. In this way the cooling air generates a film of cooling air between the holes and the end of the tube in the region of the combustion chamber opening.

Preferably the angle of the holes with respect to the longitudinal axis is in the region of 20-40 degrees. This promotes the generation of a cooling film on the interior surface of the wall and can avoid flow separation of the air entering the tube through the cooling holes. In one embodiment the angle of the holes with respect to the longitudinal axis is about 30 degrees.

In preferred embodiments, the holes are additionally angled with respect to the tube circumference, that is to say with respect to a line tangential to the tube at the positions of the respective holes on the tube circumference. In this way it is possible to induce a vortex flow of cooling air on the interior surface of the tube as the cooling air passes into the combustion chamber. This is particularly beneficial in terms of cooling the interior surface of the tube.

In preferred embodiments the holes have a tangential component substantially in the range of 30-60 degrees with respect to the tube circumference. By angling the holes with respect to the tube circumference by this amount it is possible to generate a steady vortex flow on the interior surface of the tube. In a preferred embodiment the angle of the holes with respect to the tube circumference is in the range of 40-50 degrees with respect to the tube circumference. In further preferred embodiment the angle is substantially about 45 degrees.

According to another aspect of the invention there is provided a Helmholtz resonator for a gas turbine engine combustion chamber; the said resonator having a resonator cavity and a damping tube for flow communication with the interior of the combustion chamber, the tube having at least one cooling hole extending through the wall thereof. The invention contemplates a Helmholtz resonator in which the damping tube comprises at least one cooling hole and also a combustion chamber including such a resonator.

According to another aspect of the invention there is provided a combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being supported with respect to the combustion chamber independently of the combustion chamber. This aspect of the invention is particularly suitable for gas turbine aero engine applications where the combustion chamber is not a structural component as such, in the sense that it does not support structural loads of the engine, and is constructed as a relatively lightweight component. By supporting the resonator or resonators independently of the combustion chamber strengthening of the combustion chamber can be avoided. This aspect of the invention recognises that the resonator or resonators can be more readily supported by more appropriate structural components of the engine or engine combustion section.

According to a further aspect of the invention there is provided a gas turbine engine combustion section including a combustion chamber, a combustion chamber inner casing and a combustion chamber outer casing; the said combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being supported with respect to the combustion chamber independently of the combustion chamber by the said combustion chamber inner casing or the said outer casing. Supporting the resonator or resonators by the combustion chamber inner casing or outer casing of a gas turbine engine, it is possible that no significant

strengthening of the combustion chamber, inner casing or outer casing is required. In this way it is possible to support both the weight and the operational loads, static and dynamic, using existing engine structural components in the region of the combustion chamber. The combustion chamber is not subject therefore to further loads and therefore may be of a similar weight and dimensions to that of traditional combustors.

In one preferred embodiment the resonator or resonators is/are supported by the outer casing with the resonator(s) positioned on the radially outer side of the combustion chamber. In other embodiments the resonator(s) is/are supported by the inner casing with the resonator(s) positioned on the radially inner side of the combustion chamber. The invention contemplates embodiments where the resonators are positioned on the radially outer side of the combustion chamber and conveniently supported by, or fixed to, the combustion chamber outer casing, and also embodiments where the resonators are on the radially inner side of the combustion chamber and supported both directly or indirectly by the combustion chamber inner casing. In other embodiments different resonators may be positioned on both the radially inner and outer sides of the combustion chamber. The invention therefore provides various options to the gas turbine engine designer when positioning the resonators. This may be an important design consideration due to space constraints in the combustion section of the gas turbine engine.

In embodiments where at least one resonator is supported by the inner casing and the resonator is positioned on the radially inner side of the combustion chamber, the resonator(s) may be enclosed within a cavity provided between the inner casing and a windage shield on a radially inner side of the inner casing.

The windage shield is a particularly important feature in embodiments where the resonators are positioned on the radially inner side of the combustion chamber as this can place the resonators close to the main engine shaft or shafts. The windage shield can therefore reduce windage losses which would otherwise occur due to the close proximity of the resonators to the engine shaft. The windage shield can also provide a containment structure to prevent secondary damage to the engine in the event of loss

of structural integrity of any of the resonators secured to the combustion chamber inner casing.

According to a further aspect of the invention there is provided a gas turbine engine combustion section including a combustion chamber and at least a combustion chamber inner casing; the said combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being at least partially enclosed within a cavity provided between the said inner casing and a windage shield on a radially inner side of the said casing.

In preferred embodiments the resonators are enclosed within the cavity provided between the combustion chamber inner casing and the windage shield. Preferably the resonators are circumferentially spaced around the combustion chamber.

According to another aspect of the invention there is provided a combustion chamber for a gas turbine engine comprising a plurality of Helmholtz resonators each having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said resonators being circumferentially spaced around the combustion chamber with the respective cavities of diametrically opposed resonators having substantially different volumes. This is particularly significant since it can prevent or at least reduce the formation of coupled acoustic nodes in the combustion chamber. In preferred embodiments this can be achieved by positioning the resonators circumferentially around the combustion chamber with the cavities of the respective resonators having successively smaller volumes. In this way it will be understood that the cavity having the largest volume will be positioned next to the cavity having the smallest volume.

In a further aspect of the invention there is provided a combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a resonator cavity and a damping tube in flow communication with the interior of the combustion chamber, the said cavity having substantially similar principle dimensions. For efficient

performance, the three principle dimensions, ie length, breadth and width of the cavities should be substantially the same. This can be achieved in principle when the cavities have a substantially spherical or cubic shape.

In a further aspect of the invention there is provided a combustion chamber for a gas turbine engine of the type having a plurality of heat shield type tiles lining the interior surface of the combustion chamber; the combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber with the tube having an opening in the interior of the combustion chamber substantially flush with the interior surface of the tiled lining. In embodiments where the combustion chamber has a lining on its interior surface made up of heat resistant tiles it is desirable that the resonator tube or tubes extend into the combustion chamber so that the openings of the tube or the tubes in the interior of the chamber is/are substantially flush with the interior facing surfaces of the tiles.

For the avoidance of doubt the term "combustion chamber" used herein is used interchangeably with the term "combustor" and reference to one include reference to the other.

Various embodiments of the invention will now be more particularly described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is an axisymmetric view of a gas turbine engine combustion chamber showing a Helmholtz resonator in flow communication with the interior of the chamber;

Figure 2 is a cross sectional view of the gas turbine engine combustion section shown in Figure 1 along the line II-II;

Figure 3 is a cross section view of the damping tube of the resonator along the lines III-III in the drawing of Figure 1;

Figure 4 is a cross section view of the damping tube shown in Figure 3 along the line IV-IV in the drawing of Figure 3; and

Figure 5 is a perspective view of the damping tube showing the beam paths of a